TRANSACTIONS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. XIII.

JANUARY TO DECEMBER, 1884.

NEW YORK:

PUBLISHED BY THE SOCIETY.

1884.

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AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

CCLXXII.
(Vol. XIII.—January, 1884.)

METROLOGICAL INVESTIGATIONS.

By Capt. O. E. Michaelis, M. Am. Soc. C. E.

Read at the Annual Convention, St. Paul, Minn., June 21st, 1883.

INTRODUCTION.

Before entering upon the real matter of my paper, I would like briefly to tell my fellow-members how my attention was drawn to this subject of accurate measurements.

We were directed to make a standard steel bullet for a certain purpose. The order was executed with due care and diligence, the bullet issued to the parties desiring to use it, and returned by them, with the information that it was "out of true"—so little, however, that they could not measure the error.

This is the bullet made, shown in full size in Plate I, Figure 1; enlarged five times, to show its geometrical construction and dimensions, in Figure 2.

It was claimed that the axes of the conoidal and cylindrical portions were not coincident.

Investigation showed that this was true, and that the error was, in the main, due to hardening.

A soft steel substitute was furnished, which proved satisfactory.

Under the order of Colonel Lyford, commanding officer of Frankford Arsenal, I undertook to determine the error of the original bullet, and for this purpose used our experimental measuring machine, shown in Plate II, Figure 3. This instrument is fully described in the report of the Chief of Ordnance for 1881.

It is the usual screw apparatus, operated by a wheel with graduated periphery, to which our Master Armorer, Mr. J. H. Gill, applied the Whitworth gravity contact method by means of the counterpoise beam, shown in Plate II, Figure 4, and in Plate III, Figures 6 and 7.

For use with the machine, we have certified coast survey standards of convenient lengths, and the results are in reality differences from these standards.

The bullet was firmly seated in a carriage, Plate III, Figure 5, which admitted of a controllable movement perpendicular to the measuring points of the machine.

A series of contacts were then made, which, of course, determined one cross-section contour; this, fifty times enlarged, was laid off as shown in Plate I, Figure 2.

To determine the diameters at these same points, the counterpoise beam was used on both sides of the bullet; on one side to fix it in position, with reference to the permanent measuring point of the machine, and on the other to determine that position, as shown in Figures 6 and 7, Plate III.

Afterwards the half-inch coast survey standard, Plate III, Figures 8 and 9, was substituted for the bullet, and the differences between the number representing its fixed position and those already determined were the diameters sought.

These, laid off from the corresponding points already determined, gave the cross-section contour line, Plate I, Figure 2.

It will be noticed that in making these measurements very nearly the same portion of the screw was used throughout.

Upon this cross-section contour was placed the theoretical bullet, and it was found that the axes of the two conoidal parts made an angle

PLATE I
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METROLOGICAL INVESTIGATIONS.

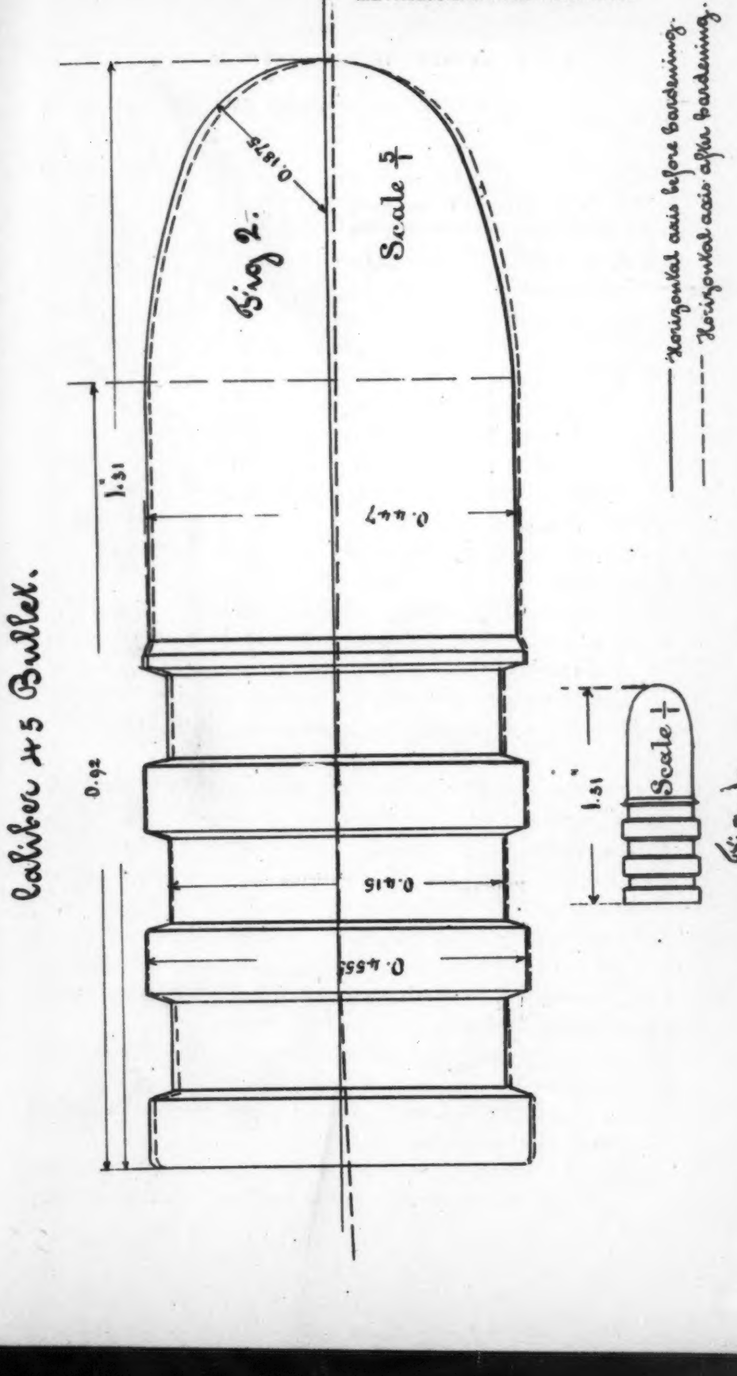

PLATE II
TRANS. AM. SOC. CIV. ENGRS.
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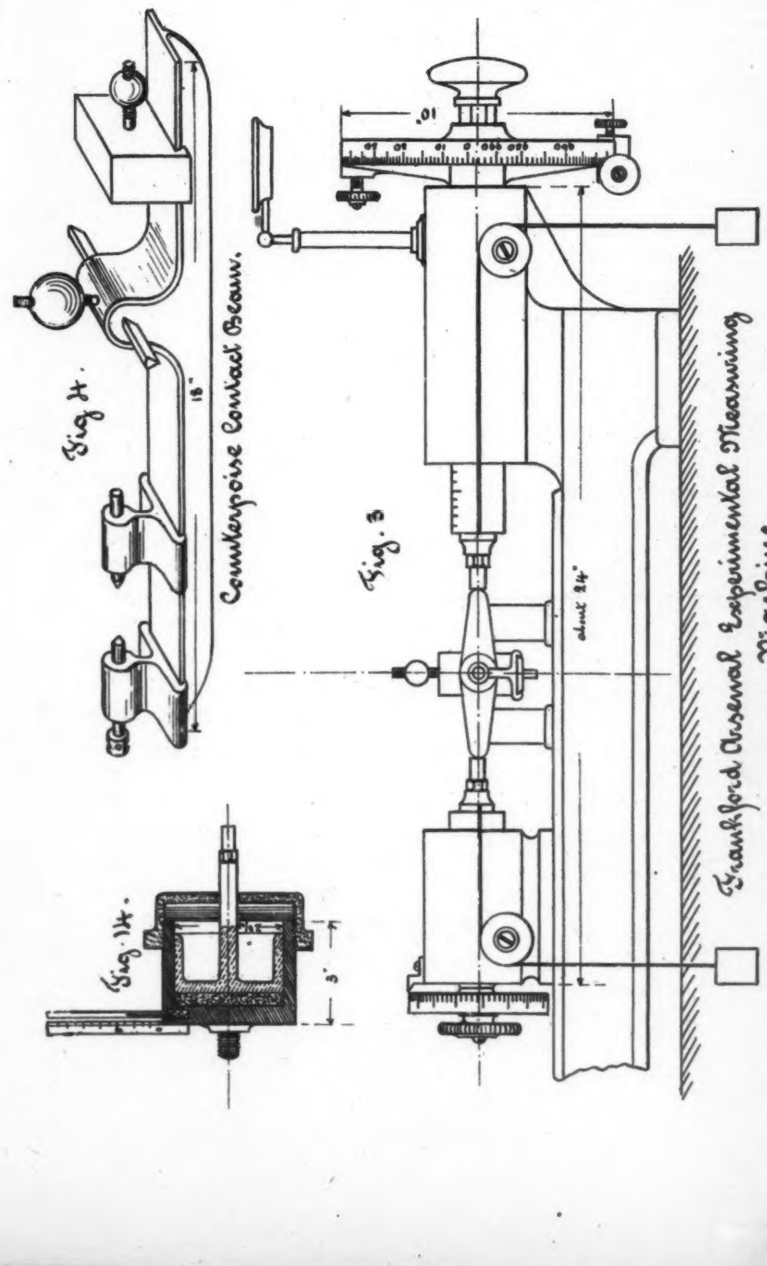
METROLOGICAL INVESTIGATIONS.



of 18 minutes with each other; therefore, at a distance of about 17 feet they will be 1 inch apart.

It is readily seen that by revolving the bullet in its seat other cross-section contours might be obtained, and that thus the whole solid could be accurately determined. One contour was deemed sufficient for our purpose.

THE MODIFIED SPHEROMETER, OR TRIPOD-CALIPER.

This work proved to me the unsatisfactory nature of the gravity touch. I became convinced that it was not a trustworthy method, and while I was seeking a more reliable means of determining contact my friend, Professor Langley, incidentally mentioned to me the fact that some measurements had been made for him by Professor Rood, of Columbia College, with the spherometer, and, as I had never heard of the apparatus, he briefly explained its principle—the determination of contact of an equilateral tripod with a glass plate, produced by the lifting of a central leg, and the subsequent determination of the same contact, the substance to be measured being interposed between the central leg and the glass plate.

Upon these data, with the aid of Mr. Henry Wernle, the Frankford Arsenal instrument maker, one of the very best mechanicians in the country, I constructed the apparatus now before you, as shown in Plate IV, Figures 10 and 11.

After obtaining some very successful results with it, I took it to Professor Rood, who showed me the spherometer he used.

I found the two instruments so very different in construction that I feel justified in calling my apparatus the tripod-caliper.

Its details are simple, requiring but little explanation.

The central leg is threaded, 100 per inch. The peripheral wheel is divided into 100 parts, and driven by an endless screw.

In this manner the millionth of an inch can be read.

It is used upon a fairly accurate plane glass, and its sensitiveness is really wonderful, the "chatter" on the glass being perceptible to the ear within $\frac{1}{40000}$ of an inch, and the tendency to revolve about the central leg, rather than slide upon the three other legs, can be made evident to both sight and touch within the $\frac{1}{500000}$ of an inch.

I give herewith the first consecutive fifty contacts; the probable error of any one observation is $1\frac{8}{10}$ millionths of an inch, and the probable error of the mean is less than $\frac{3}{10}$ of a millionth of an inch.

This includes the error of the scale, the slight and necessary movement on the glass, and my own personal equation.

The second consecutive fifty readings of contact were taken after I had had some little practice, and the results are appended.

The probable error here is $\frac{85}{100}$ of a millionth, and the probable error of the mean $\frac{1}{8}$ of a millionth of an inch.

I have taken ten consecutive measurements of some platinum foil, rolled by Tiffany for Professor Langley's bolometer, with the following results:

0″ 000 109
109
109
110
112
112
110
112
110
110

The same metal, measured at Columbia College with the spherometer, gave the following mean results:

With sharp point	= .000 093.
" blunt "	.000 100.
Thickness by weight, area and specific gravity	.000 096.

I have no difficulty in measuring other thin foils, the collodion film on a negative, a cobweb, even the interposition of moisture between the point and glass.

The possibilities of the instrument have by no means been exhausted. In the near future I propose to make one with stationary stem and movable nut, and shall endeavor to apply the audiphone to make it more sensitive acoustically.

It seems to afford a means of measuring accurately within half a millionth of an inch, and holds out hope of determining a standard recoverable unit.

I expect to be able to sensitize the moment of contact to a still greater degree by the use of carbon points in connection with a delicate galvonometer and rheostat, a principle applicable to all measuring machines.

Our observations may eliminate all accidental errors; the instrumental or screw error remains, and requires an independent method of investigation for its determination.

This brings me to the second part of my subject.

Fig 6.

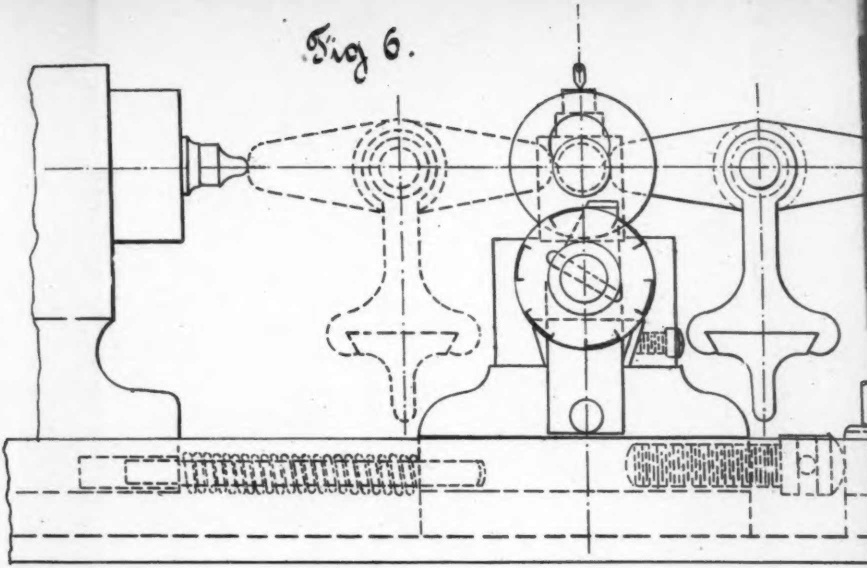
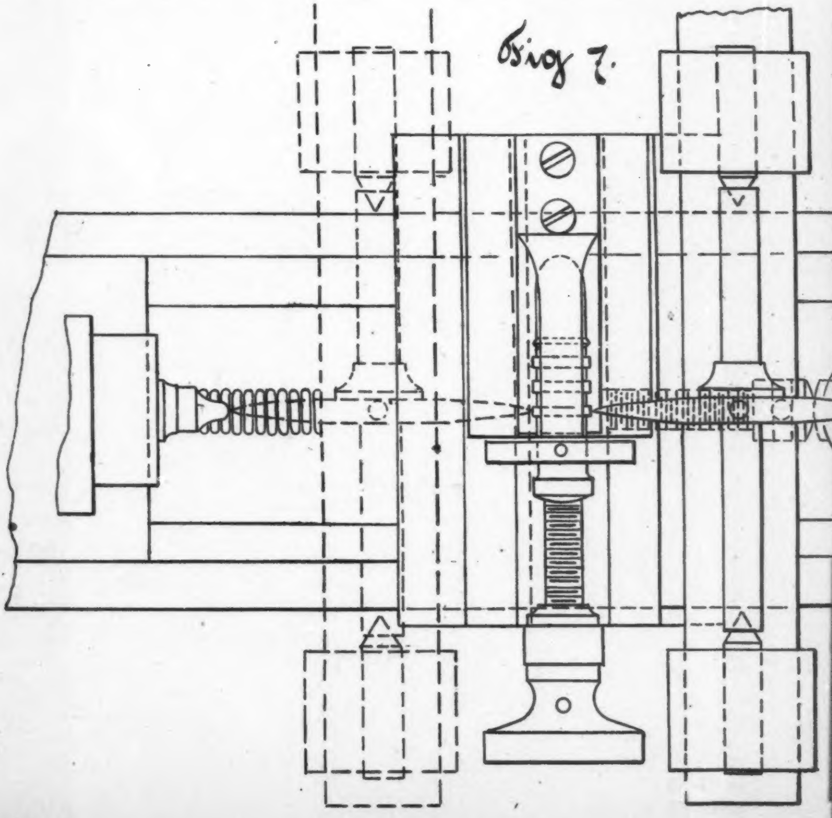


Fig 7.



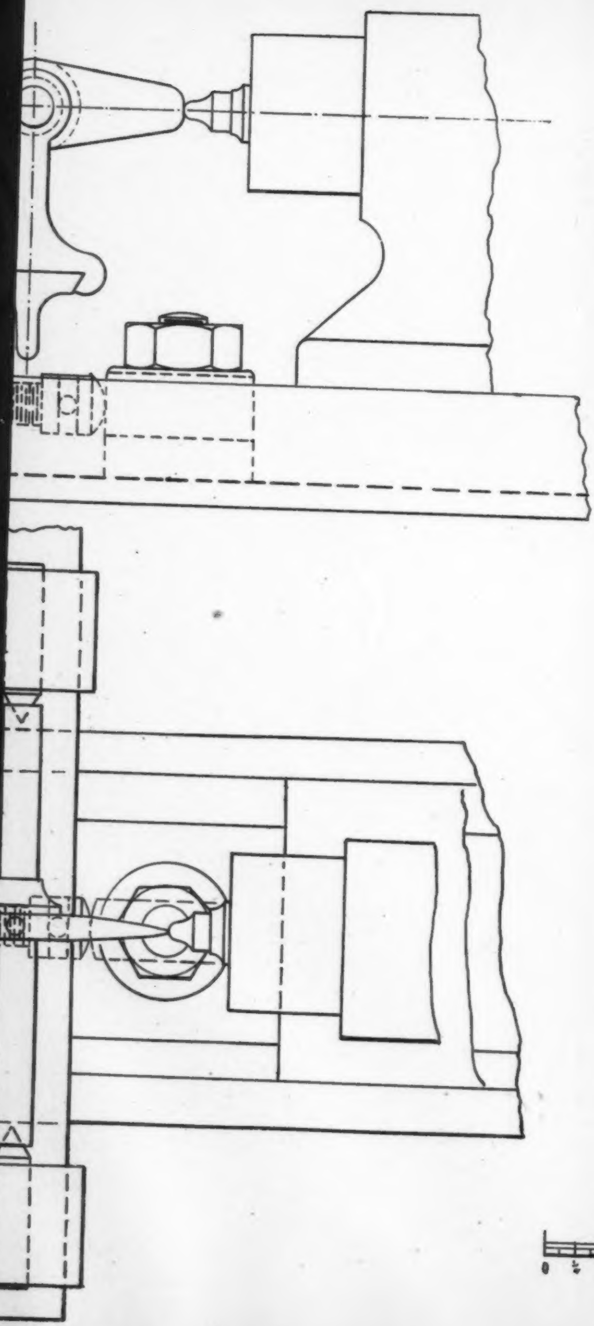


Fig. 5.

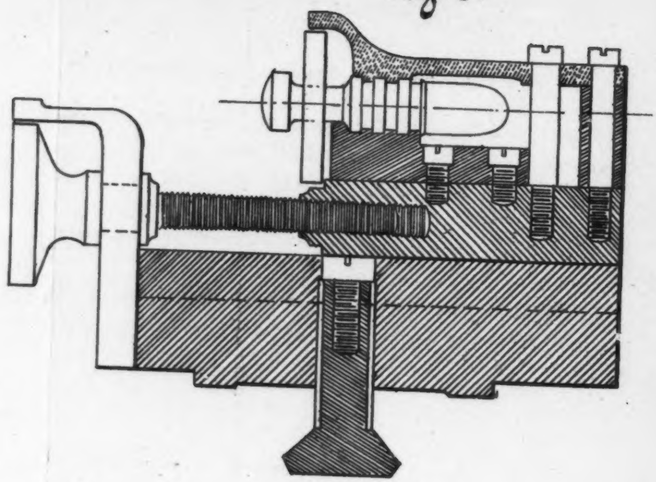


Fig 8.

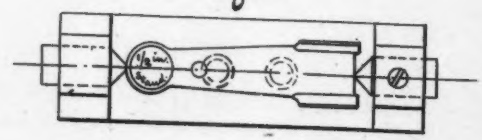


Fig 9.

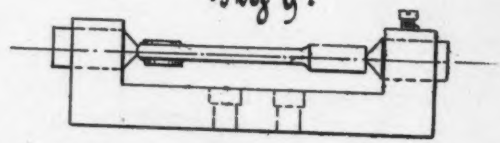


PLATE III
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The Helical Error of Screws.

The tripod-caliper readily and accurately measures the thousandth part of one turn of the measuring screw.

This screw is carefully cut, 100 per inch, and hence we assume that we obtain the $\frac{1}{100000}$ part of an inch.

This presupposes a regular, uniform pitch for at least one turn. Does this exist? It is well known that no screw can be made with perfectly uniform pitch throughout.

Various devices have been applied for the correction of this error.

Plate V, Figures 12 and 13, show the use of the inclined plane for this purpose, applied by Mr. Wernle to the Frankford Arsenal dividing engine, by means of which the motion of the nut may be accelerated or retarded, according as the error is plus or minus, dependent upon the scale used.

I have never heard of an attempt to determine the error of a single turn or fraction thereof.

Plate II, Figure 14, shows the method by which I have endeavored to do this. It is virtually a steel cylinder, in which works an accurately-ground piston. A glass tube is inserted in the cylinder, containing refined mercury.

As is evident, a very minute movement of the piston produces a comparatively enormous change of level in the tube. This apparatus was devised by Mr. Gill, with the hope of successfully substituting it in our measuring machine for the gravity contact.

It struck me that this arrangement afforded a means of ascertaining the error I was investigating.

A very fine thermometer tube was inserted, and, after considerable practice and drill, the readings for each of eight consecutive $\frac{5}{100000}$ of an inch, herewith given, were obtained, and plotted as shown on Plate VI, Figure 15, making evident the deviation of the real from the theoretical pitch.

I subsequently obtained ten readings for each of the five $\frac{1}{100000}$ of an inch comprised in the portion *a b*, Plate VI, Figure 15, which are plotted in Plate VI, Figure 16.

Of course, the areas comprised between the thread and the positive and negative deviations should be equal. Figure 15 shows that they are not, but it must be remembered that the curves are assumed between the

determined points, and Figure 16, an analysis of one section, shows how further experiment would probably rectify this apparent anomaly.

The apparatus is exceedingly delicate; the movement of the foot, a touch upon the graduated scale, changes the level of the fluid; hence the greatest care was required to arrive at any reliable results.

In all the readings the same amount of mercury was used, and the zero was made the same in all.

Of course, slight variations will occur, due to want of delicacy on the part of the observer, to the difficulty in always bringing the screw back to exactly the same point, to changes of temperature during the observation; possibly to other causes still.

I have presented these results merely to show the nature of the investigations which I have but begun, and in the hope that others interested in the subject may be induced to work in the same direction.

It matters little at which end of the unit we work. Uniform scales are absolutely essential, and they may be brought about practically just as well by the accurate determination of the $\frac{1}{100000}$ of an inch, as by the whole inch.

PLATE IV
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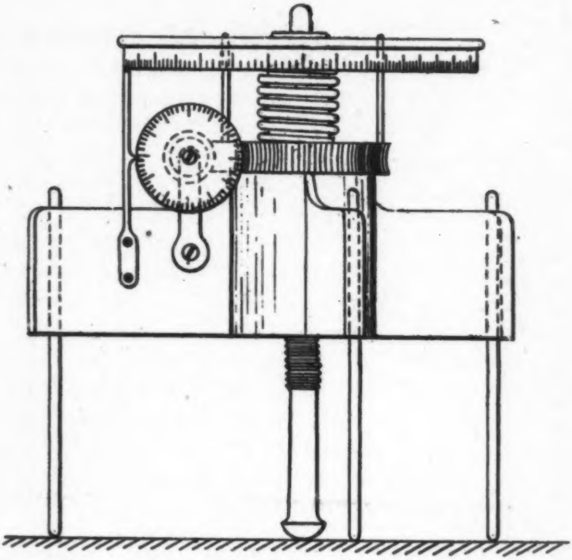
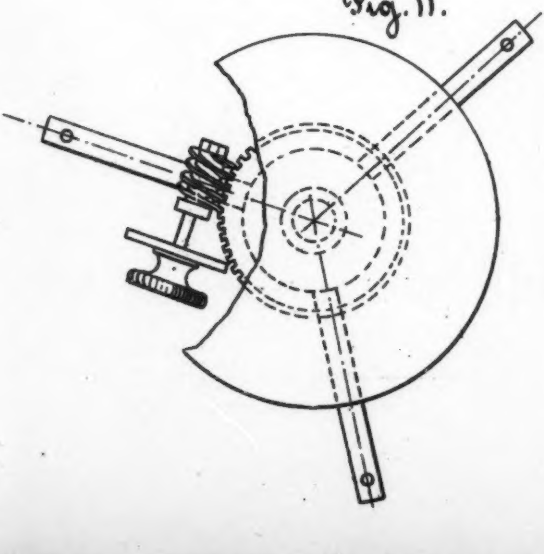
Fig 10.



Tripod-Caliper.

Fig. 11.



Determination of Contact Error of Tripod-caliper with Glass Plate.

First Fifty Consecutive Contacts. Millionths of an Inch.		Second Fifty Consecutive Contacts. Millionths of an Inch.	
102	97	13	12
100	93	12	14
100	98	13	14
100	97	12	13
101	97	11	12
99	103	11	12
99	101	10	14
95	99	13	14
98	95	10	15
98	94	13	14
100	97	13	15
98	98	14	13
96	96	12	12
96	98	14	10
94	94	14	12
95	94	14	14
97	94	14	13
99	98	14	14
100	97	12	13
100	96	13	15
102	97	14	13
101	97	14	14
102	95	14	13
103	96	13	15
101	94	13	14
2 476	2 415	320	334

Mean = 98. Mean = 13.

1.8 = Probable error of single observation = .85

.25 = Probable error of mean = .12

Height of Mercury Column due to Movement of Measuring Screw.

	From 1.80920 to 1.80925.	From 25 to 30.	From 30 to 35.	From 35 to 40.	From 40 to 45.	From 45 to 50.	From 50 to 55.	From 55 to 60.
	42	53	50	64	72	55	54	53
	44	52	50	63	73	55	55	53
	45	54	50	64	71	56	55	53
	44	54	50	63	72	57	55	53
	44	54	52	64	72	57	54	54
	44	55	51	64	73	57	55	54
	44	54	52	65	74	56	55	53
	44	53	53	64	73	57	55	53
	43	54	55	64	74	57	55	52
	43	54	55	65	74	58	56	54
Means	44	54	52	64	73	56	55	53

	From 1.80920 to 1.80921.	From 21 to 22.	From 22 to 23.	From 23 to 24.	From 24 to 25.
	5	3	1	4	3
	6	2	1	4	3
	6	2	1	4	3
	6	2	1	4	3
	6	2	1	4	3
	6	2	1	4	3
	5	2	1	4	3
	6	2	0	4	3
	5	2	0	4	3
	6	2	0	4	4
Means	6	2	1	4	3

PLATE V
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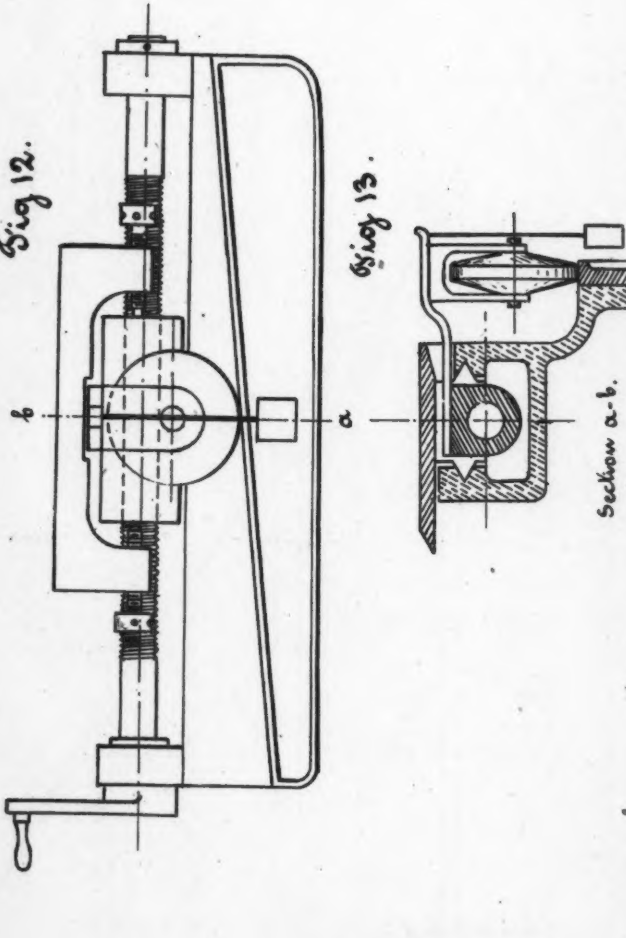

Frankford Arsenal Dividing Machine with inclined plane for correction of the total error of Scale.

1.6096

PLATE VI
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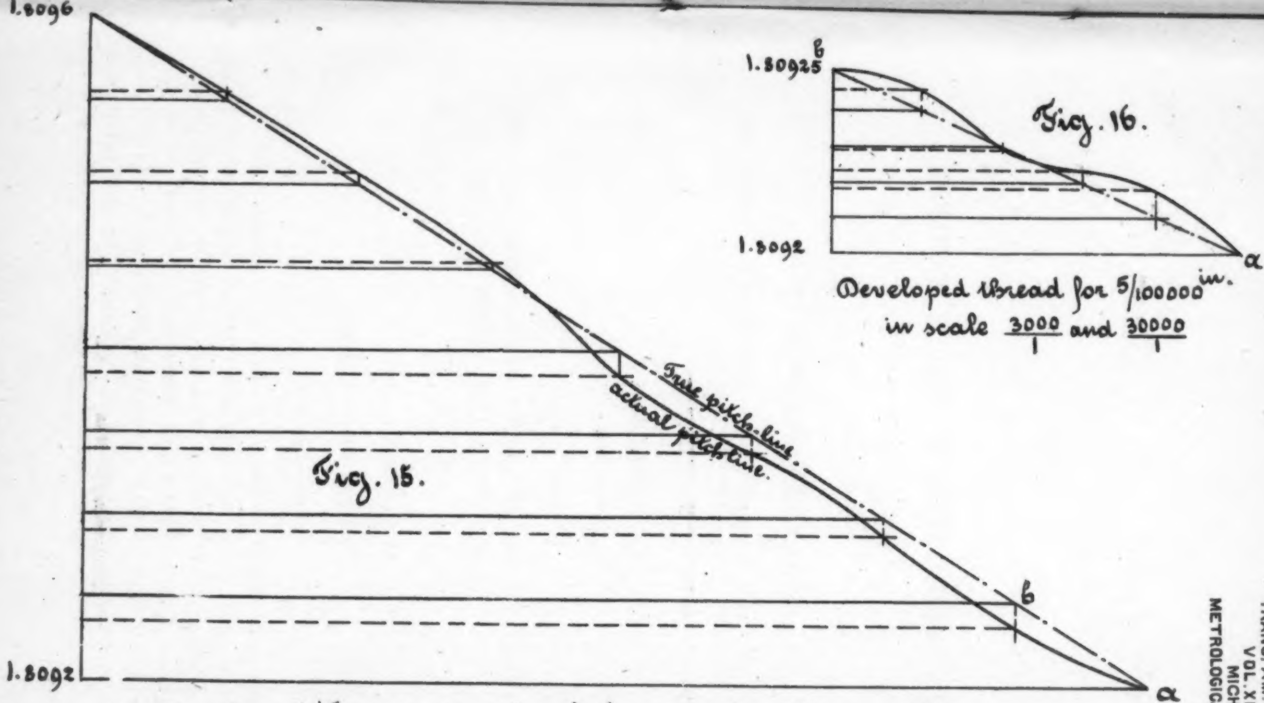

Fig. 16.

Developed thread for 5/100000 in. in scale $\frac{3000}{1}$ and $\frac{30000}{1}$

Fig. 15.

Developed Thread for 4/1000 inch. in Scale $\frac{1000}{1}$ and $\frac{10000}{1}$

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

CCLXXIII.

(Vol. XIII.—January, 1884.)

RECENT DREDGING OPERATIONS AT OAKLAND HARBOR, CALIFORNIA.

By L. J. Le Conte, M. Am. Soc. C. E.

Read December 5th, 1883.

The following is a synopsis of a report on Recent Dredging Operations at Oakland Harbor Works, California, during 1883, made under the direction of Col. G. H. Mendell, Corps of Engineers U. S. A., M. Am. Soc. C. E., by the writer, who was in immediate charge.

The trial of a new variety of pump dredger, as applied to excavating, transporting and depositing material on shore, has been progressing successfully for eight months.

This work consists in excavating a tidal-basin with the view of increasing the tidal scour at and near the entrance to the harbor.

The contract requirements are such that the material excavated must be deposited on the adjoining salt marshes, and is there retained in place by means of suitable levees or embankments that are constructed along the margin or shore line.

The total quantity put ashore by one dredge in 8 months was 250 000 cubic yards, or an average of 30 000 cubic yards per month.

The best monthly work during that time was something over 60 000 cubic yards in 230 engine hours, the average distance of transportation being 1 100 feet.

The greatest distance transported was during October, when 45 000 cubic yards were delivered on shore in 190 engine hours, the material being forced through a length of 1 600 to 2 000 feet of 20-inch wrought-iron pipe.*

Description of Dredges.

This machine is supposed to be an improvement on the appliances used at the Grand Canal Works, Amsterdam. In the last mentioned works there are two separate engines; one does the work of excavation, and the other takes the spoil and forces it through a line of pipe to its proper destination. The material is therefore handled twice. The new variety of pump dredge now under trial may be said to combine these two operations in one machine. The cutting apparatus of this dredge is a horizontal wheel, with ordinary plows rigged on the lower face.

The rotation of this wheel does the excavation required. In some soft material it is unnecessary.

Over this "cutter," and partly surrounding it, is a hood or inverted basin that only allows water to enter from beneath. Into the top of this basin or hood, and somewhat to one side of its geometrical centre, is placed the lower end of a 20-inch suction pipe which leads up vertically to a large centrifugal pump, runner 6 feet diameter.

From this pump there extends a line of wrought-iron pipe, supported partly on pontoons and partly on the marsh, to, and several hundred feet within the enclosed tract that is to be reclaimed.

* Since writing the above the work of the month of November has been completed. During that month there were excavated and put ashore 41 000 cubic yards in 190 engine hours, and this amount of material was forced through 2 850 feet of 20-inch pipe.

PLATE VII
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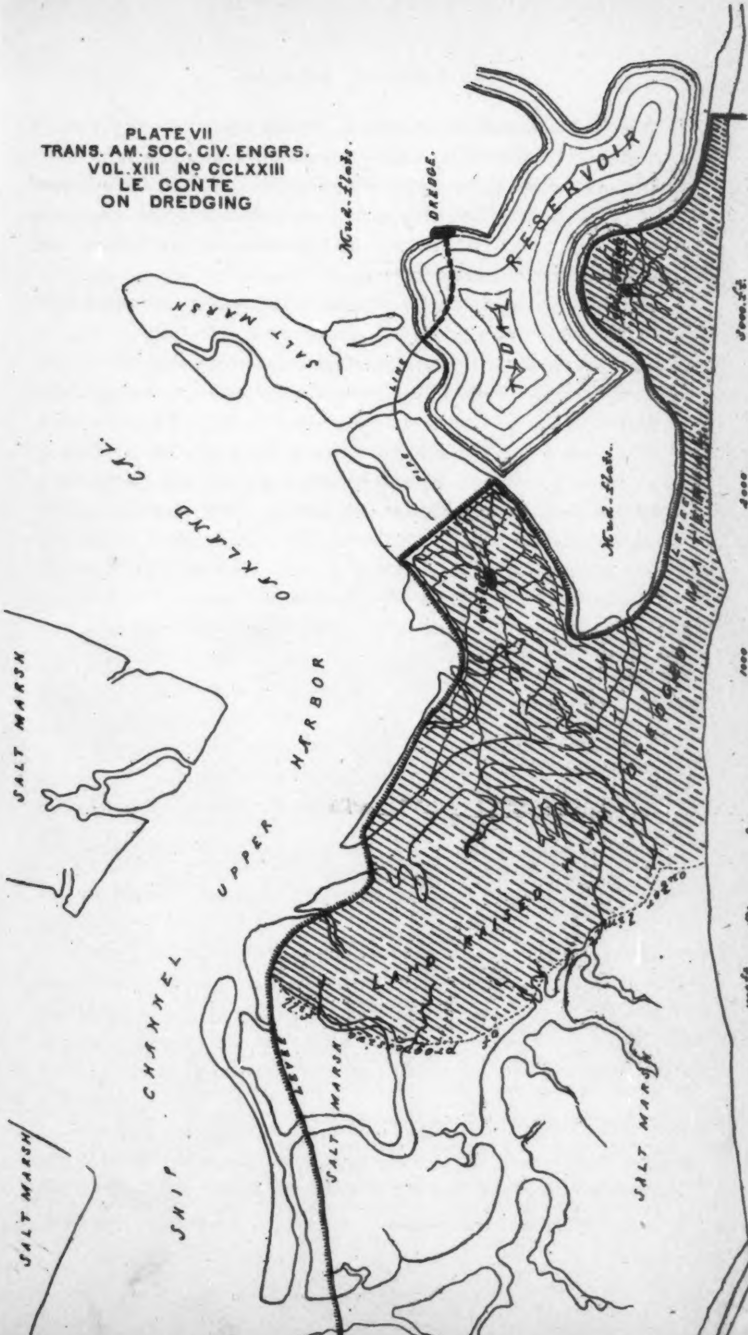
LE CONTE
ON DREDGING



It will be seen, then, that the material, after leaving the "cutter," is taken up by the water entering the suction pipe leading to the pump—passes directly through the same, and thence continues through a line of pipe to its destination on shore. At no time during transportation does the material come to a state of rest.

The percentage of material transported by the column of water has been subject to great variation, namely, from nothing, or clean water, to as high as 40 per cent. by volume. Experience has shown, however, that, in this particular class of material, it is not advisable to carry more than 15 per cent. The reason is plain and practical. When the muddy water escapes from the outlet or discharge-pipe, it is found highly important that the percentage of water should be sufficiently great to ensure a widespread and uniform distribution of the material.

The character of the material excavated is quite uniform, and may be described as being a sticky, blue clayey mud. A man weighing 150 pounds can wade all over these mud flats without sinking into the material deeper than his knees. Occasionally the dredge will cut into lenticular masses of blue clay of remarkable purity, and as a result the discharge-pipe belches forth quite a large percentage of clay balls, in all sizes, from mere pellets to some as large as a man's head. * * * *

As to the power required :

The engines in use comprise two 16-inch x 20-inch engines, used exclusively for driving the centrifugal pump; two 12-inch x 12-inch engines for driving the cutting apparatus, swinging gear, winches, speed hoists, etc.

Two 100 horse-power boilers, generally carrying 90 to 95 pounds of steam ; these boilers furnish steam to the above engines and bilge pump or primer.

Remark.—I would here state that the mounting and general setting up of the pump engines was very poor and unstable, so much so that it was found unsafe to run at a greater speed than 130 revolutions per minute. The engines are rigged directly on to the pump shaft. The existing dredge is susceptible of many improvements and greater general efficiency.

The daily regular expenses incurred during the general manipulation of the plant is naturally the next question to be taken up. Operations have been going on for too short a space of time to develop reliable data.

Long experience on this coast has convinced me that these regular expense estimates are invariably too low, and especially as regards the item for repairs. With these cautionary remarks, I submit the following as being a "first approximation" to the regular expense account:

PER DIEM EXPENSES—10 HOURS.

Coal, 4 tons, @ $7	$28.00
Oils, 1 gal., @ $0.75	.75
Water, 7 000 gals	7.00
Attendance: 1 capt., $5; 2 engrs., $8; 2 firemen, $4; 3 deck-hands, $6; 1 cook, $2; 1 water-tender, $2	27.00
Board: 10 men, @ $0.50	5.00
Interest on 1st cost $50 000	10.00
Depreciation, $\frac{1}{20}$	9.00
Repairs on dredge and pipe line	10.00
Insurance on $25 000 (say) 8 per cent	5.55
Total daily expenses	$102.30

Or, in round numbers, say $100 per diem.

Extra Expenses.—In addition to the above regular expenses, there are, of course, others which are by nature peculiar to the requirements of the contract now in force. These may be summarized as follows:

1st. The construction and maintenance of retaining levees or embankments for the purpose of confining the freshly dredged material.

2d. The permanent employment of a crew of 9 to 10 men on shore, whose duties are to guide the flow and general distribution of the material as the filling progresses towards completion.

These two items have, collectively, added considerably to the general expenses, but at the same time should, in all equity, be borne by the landed proprietors whose property is being greatly improved.

Up to date these expenses have reached the neighborhood of $10 000. A detailed account of these inshore operations is omitted, since experience as yet is limited, and furthermore, they will vary largely in character and cost with every situation, depending chiefly on local topographic features, nature of ground, etc.

Character of Resultant Deposit.

Tract No. 1 has now been filled and allowed to rest for two months at least. The filling is most satisfactory in every respect. The complete distribution of the material is very striking to the eye and to my mind constitutes the very essence of success in all dredging operations of this character. The important fact was developed that a large percentage of water mixed with the mud was necessary in order to insure a complete and uniform distribution of the deposited material. There is no other means or power which can do this work of distribution so thoroughly and so cheap.

The deposit, taken as a whole, may be described as a cluster of cones whose side slopes are very flat, not more than 1.5 per cent., and frequently so slight as to appear almost level. The apexes of these cones mark the successive positions of the end of the discharge-pipe.

Final Remarks.

Every harbor engineer of experience has been more or less compelled, for economical reasons, to acknowledge the unavoidable necessity of dumping dredged material into deep water navigable channels. This reprehensible practice has been increasing in dimensions, year by year, until now the hurtful effects are beginning to show themselves. These effects take the form of, first, prodigious filling in of the flats ; second, the narrowing of the deep water or ship channels. The second is a natural sequence of the first, and is brought about by the serious diminution of tidal prism, which is itself due to the shoaling or filling in of the flats ; they are mutually dependent.

It is with great relief, therefore, we are able to report important and reliable steps towards cheap dredging and cheap disposal of material to a profit as well as a public benefit.

Past experience on the Pacific coast has shown that the cost of filling in low lands with dredged material has generally been twice the cost of ordinary dredging with dump scows, &c. In other words, the entire bulk of material had to be handled twice. It has never been done with success heretofore for less than 24 cents per cubic yard, measured in scows.

With the new pump dredge, however, we have an average of 30 000 cubic yards, measured in the cut at the close of each month's work, at a

maximum cost of ten cents per cubic yard; and in one month's work of twenty-three days' work, 60 000 cubic yards, at a cost of 5 cents per cubic yard, placed on shore, at a distance of 1 600 to 2 000 feet from the site of the dredge while at work.

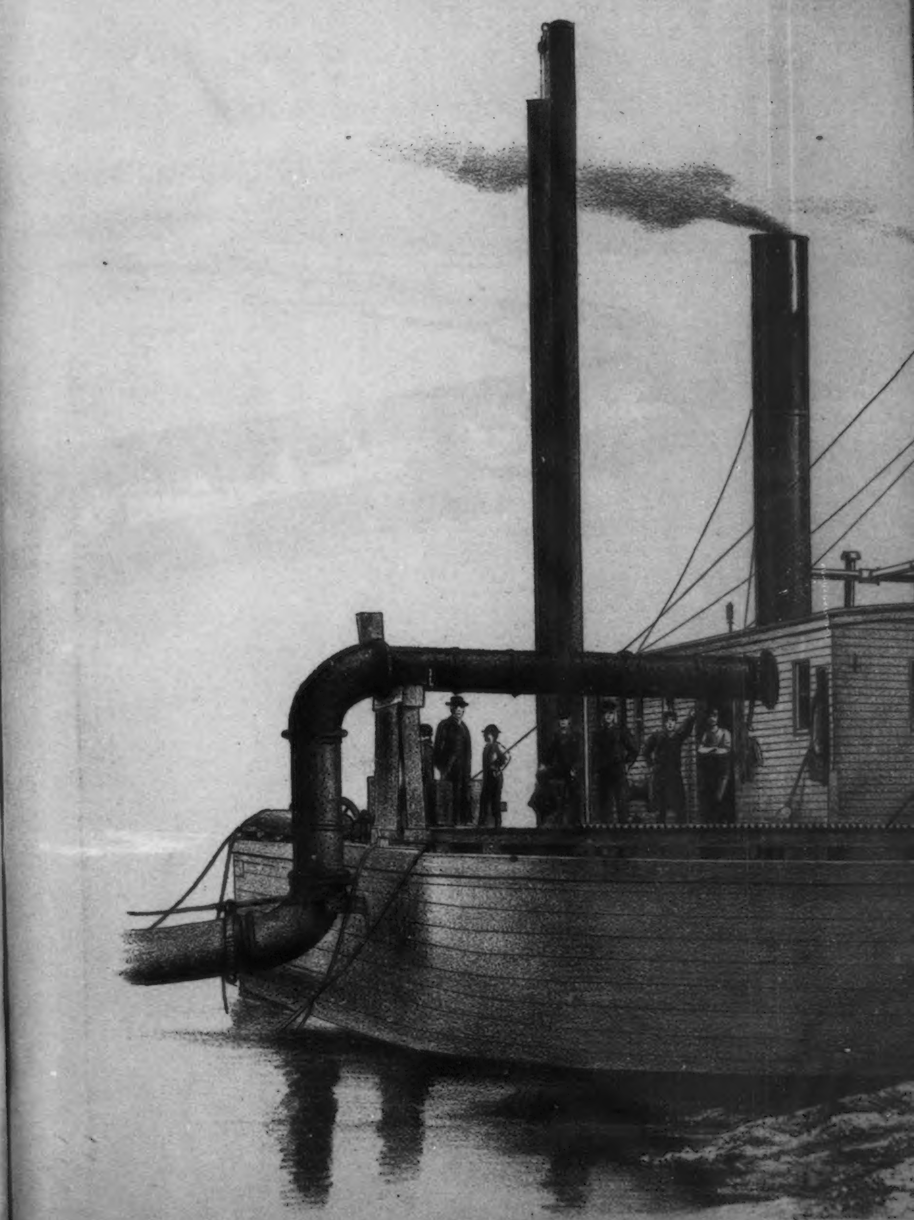
These recent dredging experiments put new life into harbor and river works, and in many places will unquestionably be of paramount importance both to the engineer and owners of low lands.

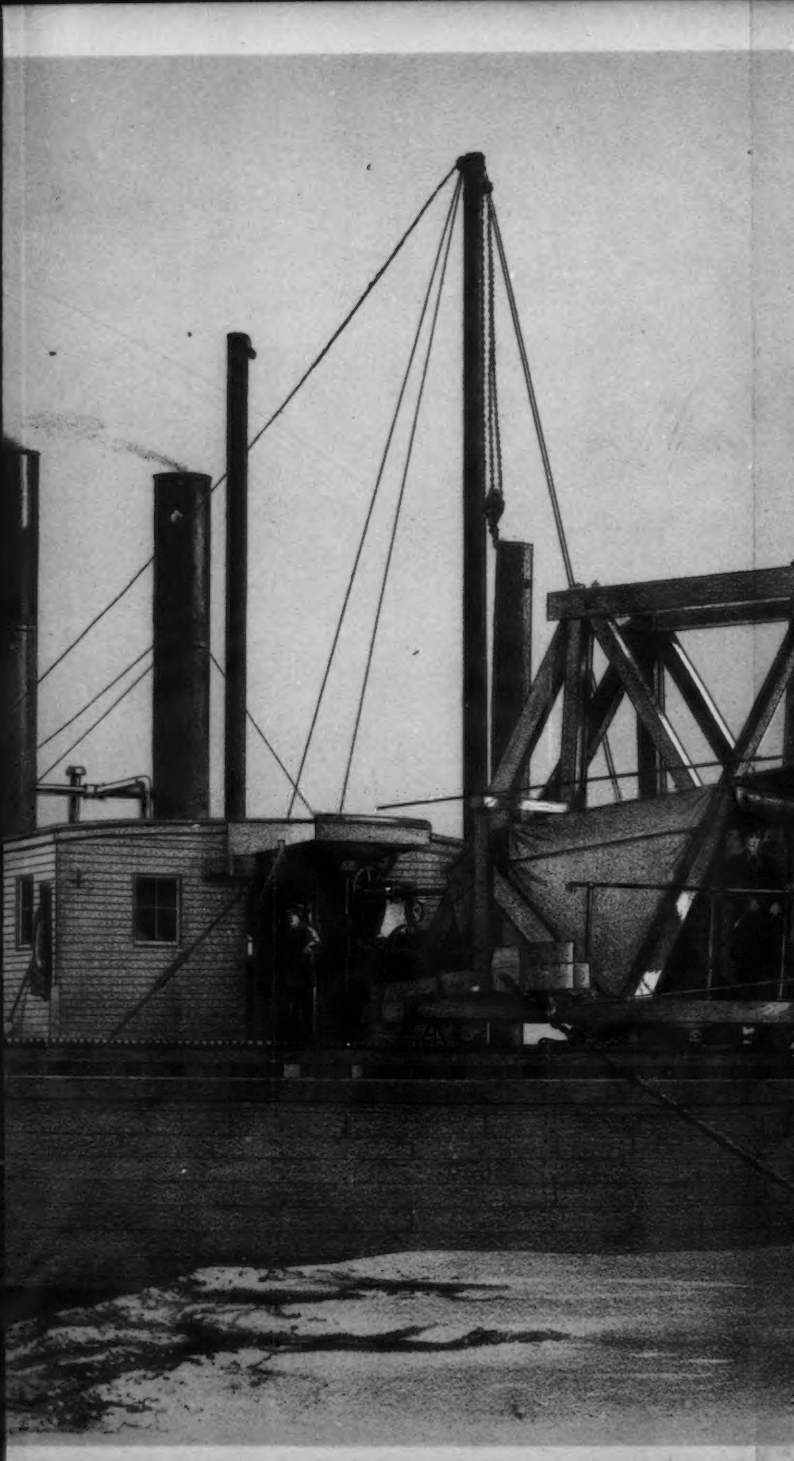
NOTE.—Plate VII shows the Tidal Basin at Oakland Harbor, California, with the location of the dredge at work, and the line of 20-inch pipe to point of deposit.

Plate VIII shows the dredge. This is A. W. Von Schmidt's Improved Dredging Machine. The length of the boat is 100 feet, beam 50 feet, depth of hold 7 feet. The pump is a rotary centrifugal, with a runner 6 feet diameter. The engines to run the pump are two, each 16-inch cylinder, 20-inch stroke, 134 revolutions per minute. The engines to run the plow are two, each 12-inch diameter, 12-inch stroke, 120 revolutions per minute. There are two boilers, each 60 inches diameter, 16 feet long, 66 tubes, 3½ inches diameter. Steam carried, 85 pounds.

Plate IX shows the method of supporting the discharge pipe, 20 inches diameter, 2 850 feet long, on pontoons. The pipes have iron ball socket joints and rubber sleeve connections.

DREDGING MACHINE
A.W. VON SCHMIDT'S
OAKLAND HARBOR, CALIFORNIA.





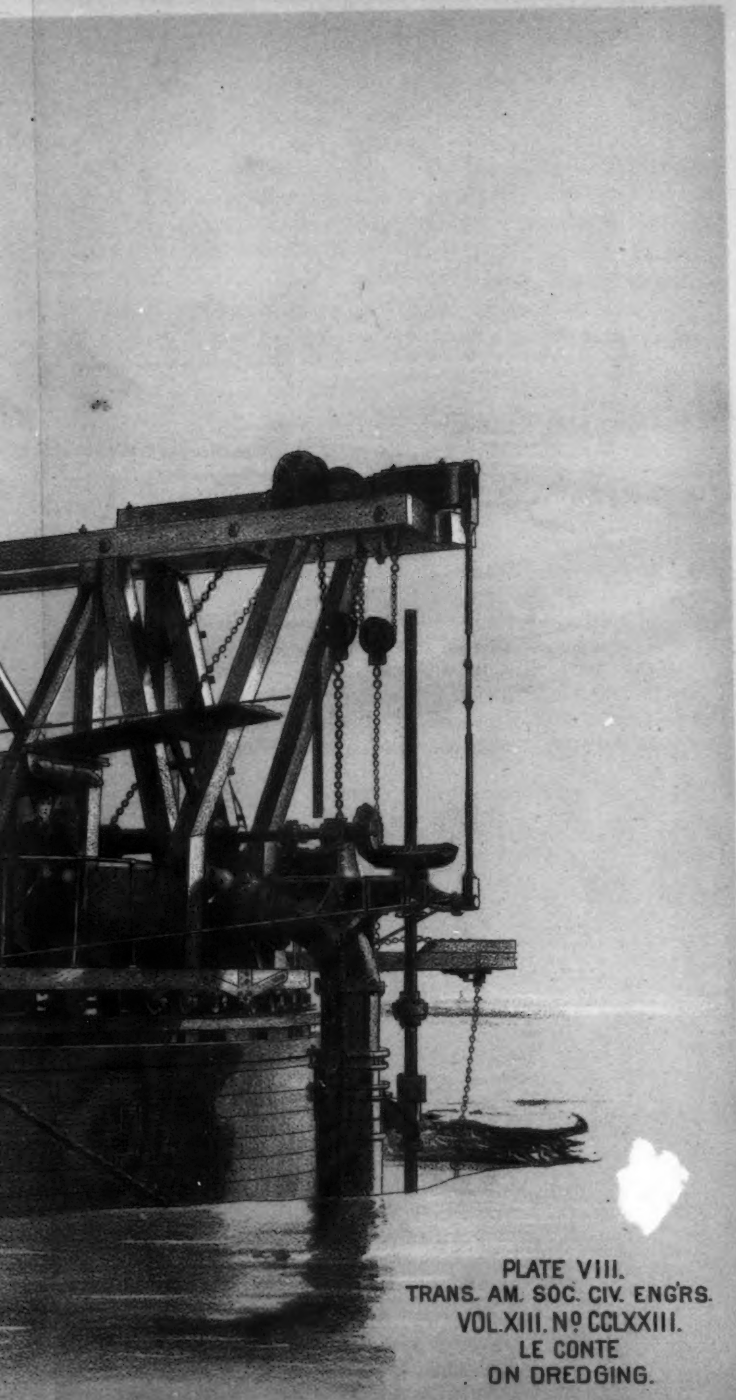
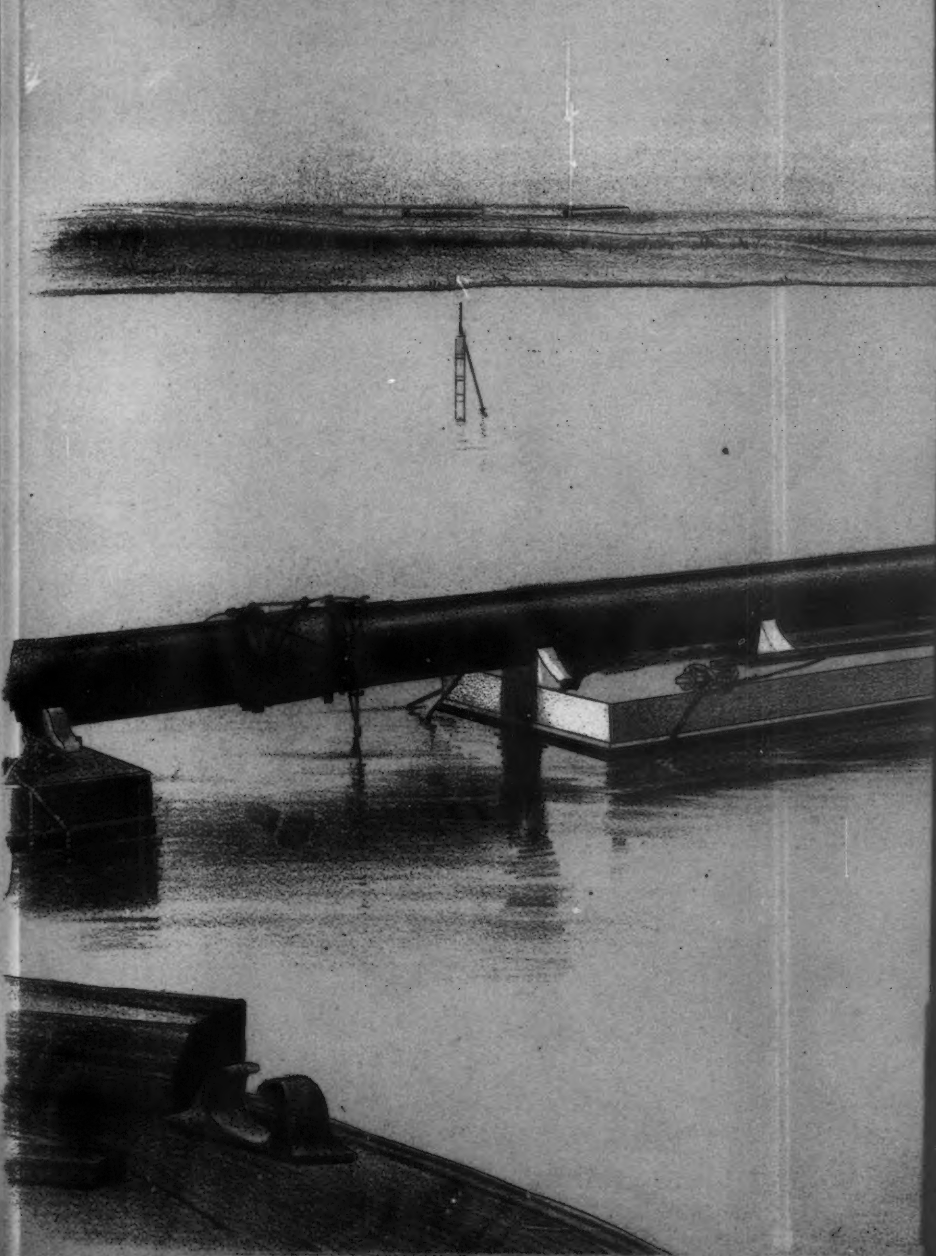
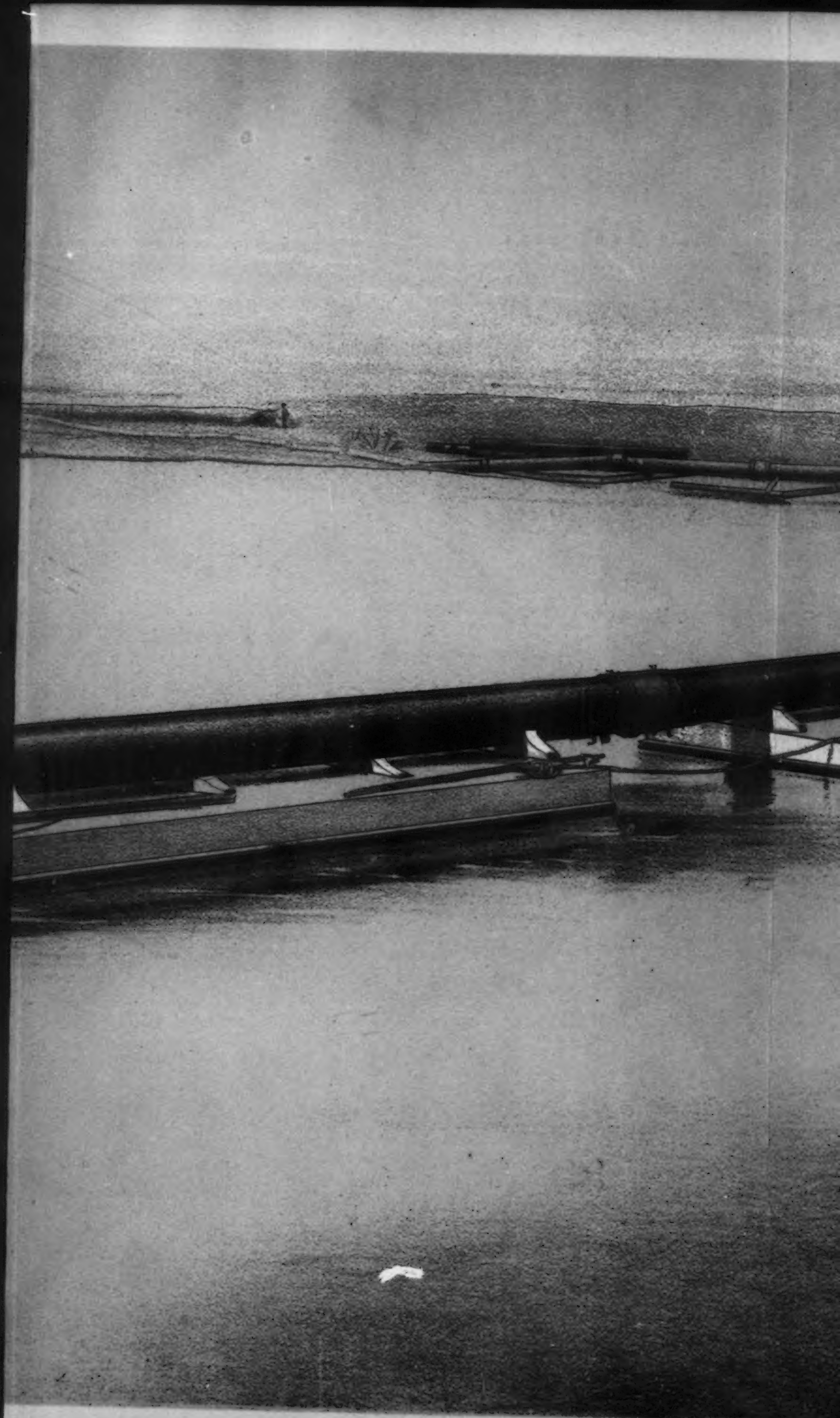


PLATE VIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XIII. Nº CCLXXIII.
LE CONTE
ON DREDGING.

DISCHARGE PIPES FROM
VON SCHMIDT'S DREDGE
OAKLAND HARBOR, CAL.





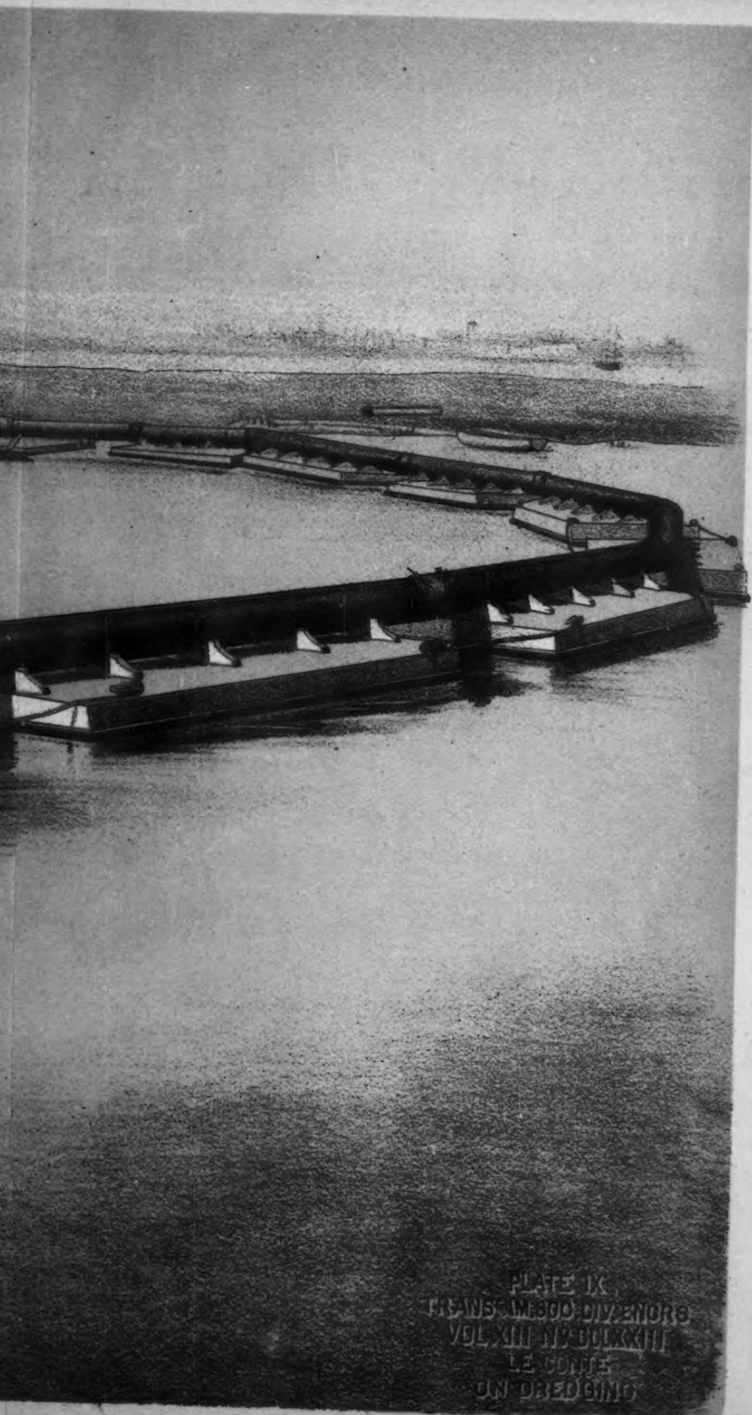


PLATE IX.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XIII No. DLXXIII
LE CONTE
ON DREDGING